BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Determination of Lunar Flying Vehicle Range and Payload Capabilities for Mission Planning Purposes - Case 720

DATE: Dec. 26, 1967

FROM: D. R. Valley

ABSTRACT

This memorandum presents a brief description and evaluation of a recent Bell Aerosystems report containing parametric performance data on the lunar flying vehicle for lunar mission applications.

A graphical presentation of the basic Bell Aerosystems data has been included as a tool for estimating flying vehicle performance in terms of range and payload capabilities for mission planning purposes.

(NASA-CR-93121) DETERMINATION OF LUNAR FLYING VEHICLE RANGE AND PAYLCAD CAPABILITIES FOR MISSION PLANNING PURPOSES - CASE 720 (Bellcomm, Inc.) 13 p

N79-71815

Unclas
00/12 12630

FF No. 2(C

(PAGES) [redacted] (CODE)

(NASA CR OR TMX OR AD NUMBER) 3/ (CATEGORY)

[redacted]

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Determination of Lunar Flying Vehicle Range and Payload Capabilities for Mission Planning Purposes - Case 720

DATE: Dec. 26, 1967

FROM: D. R. Valley

MEMORANDUM FOR FILE

A recent Bell Aerosystems report[1] on a study of lunar flying vehicle mission applications contained some very useful vehicle performance data. Figure 1 shows the basic data presented in a plot of the vehicle's ΔV requirements vs range. The "Optimum Cruise" type of trajectory is not clearly defined in the report, but essentially is a semi-ballistic type flight. Full thrust for a timed period, a semi-coast period at minimum thrust, and a variable thrust landing profile make up the optimum cruise trajectory. Figure 2 shows the altitude and cruise velocity obtained by the vehicle as a function of the flight range. As an example, a 5 nm optimum cruise flight would carry the vehicle to a 3000 ft altitude and the cruise velocity (horizontal) would be about 310 ft/sec (210 mph). The optimum cruise flight is claimed to be the most efficient, but results in rather high altitudes and vehicle speeds. It probably will be more desirable to fly lower and slower over an unknown lunar terrain. The Bell Aerosystems report evaluated the ΔV penalties associated with flying off-optimum trajectories. The data presented in the report for flat-top type trajectories has been extrapolated to Figure 1 for horizontal velocities of 100 and 150 ft per second. The vehicle altitude for these flat-top trajectories can be roughly bracketed between 200 and 500 ft.

Figure 1 can be used to evaluate the ΔV penalty associated with "lower and slower" flights. Once again taking a 5 nm flight as an example, reducing the cruise velocity from optimum (310 ft/sec) to 150 ft/sec increases the ΔV requirement by more than 200 ft/sec. Slowing the flight to a 100 ft/sec cruise velocity requires a 500 ft/sec ΔV capability increase over the optimum cruise value. Looking at the data in another fashion, the reduction in range capability for a slower flight can readily be estimated. For the same ΔV as the optimum 5 nm flight, the range would have to be reduced to 4.1 and 3.5 nm for lower cruise velocities of 150 and 100 ft/sec respectively. This represents a reduction of 18-30% in the vehicle's range capability.

---

(1) Flight Test of a One-Man Flying Vehicle Volume II-Final Report-Mission Applications Studies - Bell Aerosystems - Report No.2330-950002, July 1967.

The Bell Aerosystems report used the "Optimum Cruise" data to present a variety of mission oriented, vehicle capability charts. These charts relate vehicle propellant requirements to flight ranges and various payload values. In using the charts from this report, one should be aware of two factors that place the results obtained on the optomistic side:

1. All ΔV requirements are based on the "Optimum Cruise" trajectories which require higher and faster flights than may be desirable for exploration type missions.

2. Propellant requirements obtainable from the charts are based on a tank loading just sufficient to perform the mission. In reality, the flying vehicle will probably always start a mission with full tanks and thus will burn more propellant just to carry the reserve for missions not requiring the full tank capacity.

The report presents mission data analysis for three different size flying vehicles. The largest of the three is the most popular in the present day mission planning circles. This vehicle's weight and propellant capacity are shown on Figure 3 which was developed to display the basic Bell Aerosystems data in a slightly different fashion. The maximum ΔV capability of the vehicle is plotted as a function of the payload weight carried to a destination and the payload returned to the base. The ΔV capability in turn can be converted to vehicle range using the Bell Aerosystems' data from Figure 1. Three scales of vehicle range are shown on Figure 3; for the optimum cruise and for flat-top trajectories with horizontal velocities of 150 and 100 ft/sec.

Figure 3 can be used to evaluate flying vehicle range capabilities for missions involving a simple round trip flight. The chart allows unlimited combinations of payloads up to the vehicle's stated payload capability of 300 lbs.

The 300 lb payload capacity is the main reason for the popularity of this size flying unit. It offers rescue capability for an astronaut (300 lbs with suit and PLSS). The use of Figure 3 can be illustrated by determining the maximum range at which rescue can be accomplished. For the rescue type flight, no payload would be carried to the destination, but 300 lbs would be returned to the base. Point (1) on Figure 3 represents the intersection of this payload combination. Reading horizontally from this point the vehicle's maximum capability may be determined in terms of either ΔV or range. Point (1) indicates a ΔV capability of 1710 ft/sec for each leg of the flight, and from the range scales a maximum rescue range of 7, 5.5, or 4.5 nm is indicated depending on the type of flight trajectory assumed.

As one other example, point (2) on Figure 3 indicates that a flight carrying out a 200 lb payload and returning 100 lbs has a maximum range of approximately 7.3, 5.7, or 4.6 nm, depending on the selected trajectory.

Figure 3 can be used for a reasonably accurate evaluation of a lunar flying vehicle's round trip capability for mission planning purposes. If a particular combination of payloads is desired, the range capability can be easily determined; or conversely, for a given range, the possible payload combinations can be selected.

Recent indications are that a suited astronaut will weigh in the order of 400 lbs. This will place greater requirements on the flying unit for rescue applications, and probably will result in a somewhat larger vehicle than presented on Fig. 3. Figure 4 has been included to provide a means of evaluating the capability of a larger vehicle with the heavier astronaut weight reflected. The data is similar to that shown on Fig. 3 except that the payload combinations are expanded to include a 400 lb limit and the vehicle's propellant loading has been increased to 300 lbs.

Figures 3 and 4 are limited to simple round trip flights, and are restricted to a specific vehicle size. Evaluation of a flying vehicle's performance for missions involving several short flights cannot be presented in as clean a graphical form. The large number of variables such as range, ΔV, payloads, propellant requirement, number of flights, flying vehicle size and type of trajectory do not lend themselves to the simple graphical solutions of Figures 3 and 4.

Figures 5, 6 and 7 can be used to determine a lunar flying unit's capabilities for the "multi-hop" type of mission. These charts are a plot of the vehicle's propellant requirements vs range with the lift-off weight as a variable. There is a separate graph for each of the three trajectory types; optimum cruise (Fig. 5), and flat-top trajectories with horizontal velocities of 150 and 100 ft/sec (Figures 6 and 7 respectively). These figures can be used to determine the flying unit's propellant requirements for multi-hop missions with flexibility as to the flying unit size, payload weights carried on each flight, and the number of flights. Mission performance solutions cannot be read directly, but with a little "bookkeeping" the total mission propellant requirements can be obtained.

Knowing the initial lift-off weight of the vehicle which includes weight of the structure, crew, propellant, and payload, the propellant burned for the first hop can be read as a function of the flight range desired.

Reducing the initial lift-off weight by the amount of propellant burned and making any payload adjustments desired for the second hop gives the lift-off weight for that flight. This procedure can be repeated for as many flights as desired and the total amount of propellant accumulated until the mission sequence of short flights is completed.

A sample mission involving three intermediate stops (4 hops) by the flying unit prior to its return will be assumed to illustrate the use of figures 5, 6 or 7:

Flight	Range	Payload
1	2 nm	300 lbs
2	3 nm	100 lbs
3	1 nm	50 lbs
4	4 nm	10 lbs

For purposes of this illustration, the larger of Bell Aerosystem's flying units included in their report[1] will be assumed. Figure 3 shows a weight statement for this vehicle which has a total weight of 713 lbs (less payload). We will further assume that the optimum cruise flight trajectory will be used (Figure 5).

Figure 5 is entered at point 1 which corresponds to the 2 nm range of the first hop and the vehicle lift-off weight of 1013 lbs (713 lbs + 300 lb payload). The propellant burned on the first hop is 81 lbs. The lift-off weight for the second hop can now be determined as follows:

713 lbs		Initial vehicle weight
- 81 lbs		Propellant burned on 1st hop
+ 100 lbs		Payload to be carried to second stop
732 lbs	=	Lift-off weight for second flight

Figure 5 is again entered at point 2 (732 lbs lift-off weight and 3 nm range).

Propellant burned on 2nd flight = 76 lbs, lift-off weight for 3rd flight = 713-81-76+50 = 606 lbs. Figure 5 is entered at point 3 (606 lb lift-off weight and 1 nm range).

Propellant burned on 3rd flight = 31 lbs, lift-off weight for 4th flight = 713-81-76-31+10 = 535 lbs. Figure 5 is entered at point 4 (535 lbs lift-off weight and 4 nm range).

Propellant burned on final flight = 65 lbs. The total propellant required for the four-flight mission is 253 lbs (81+76+31+65).

The same mission can be analyzed for flights using the flat-top trajectories by using Figures 6 or 7 in exactly the same manner. The propellant required for the 150 ft/sec flat-top (Figure 6) is 272 lbs, and 291 lbs are required for the 100 ft/sec trajectories (Figure 7). It is interesting to note that the latter value of 291 lbs is over the vehicle's tank capacity (273 lbs), which means that the sample mission could not be flown at the 100 ft/sec velocity with the size flying unit selected.

In view of recent increases in suited astronaut's weight ($\sim$400 lbs) and the likelihood of larger flying units, it should be remembered that Figures 5, 6 and 7 are relatively* independent of flying vehicle size. Within the general range of lunar flying vehicle weights under consideration, these charts should remain a useful mission planning tool.

In summary, this memorandum graphically presents Bell Aerosystems' "ΔV vs Range" data in forms designed to give the widest possible flexibility for evaluating the capabilities of a lunar flying vehicle. Payload combinations can be varied, flight trajectories can be selected and may even be intermixed by using Figures 5, 6 and 7 for the individual hops of multi-flight missions. If carefully used, the included charts should provide an accurate assessment of the flying unit's capability for a variety of specific mission applications.

D. R. Valley

1012-DRV-sjh D. R. Valley

Attachment:
Figures 1 - 7

*(ΔV requirements due to gravity losses will be affected by possible changes in the vehicle's thrust-to-weight ratio).

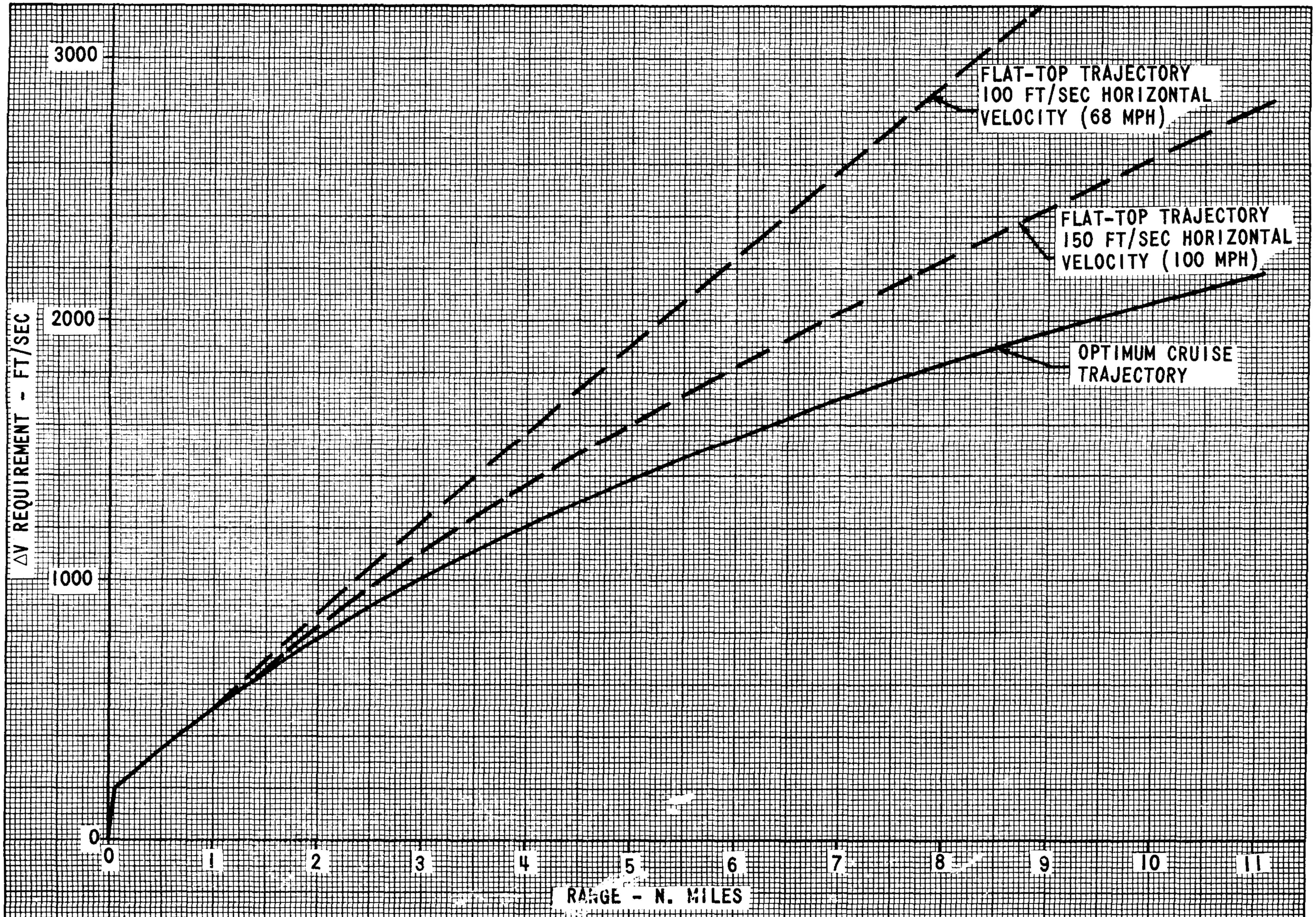

FIGURE 1 - LUNAR FLYING VEHICLE RANGE vs. ΔV REQUIRED (BELL AEROSYSTEMS DATA)

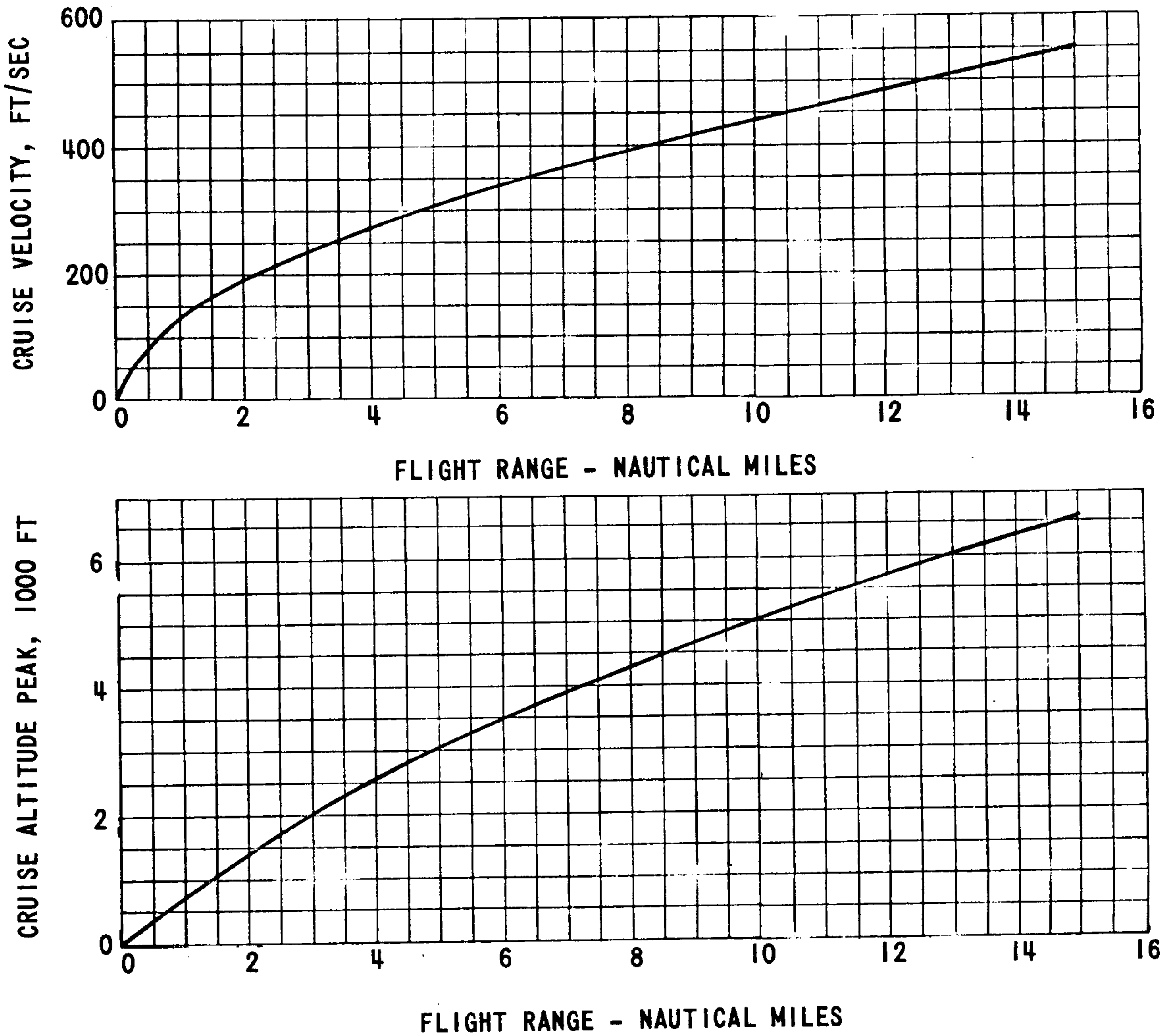

FIGURE 2 - CRUISE CONDITIONS FOR MOST EFFICIENT FLIGHT (OBTAINED FROM BELL AEROSYSTEMS REPORT[1])

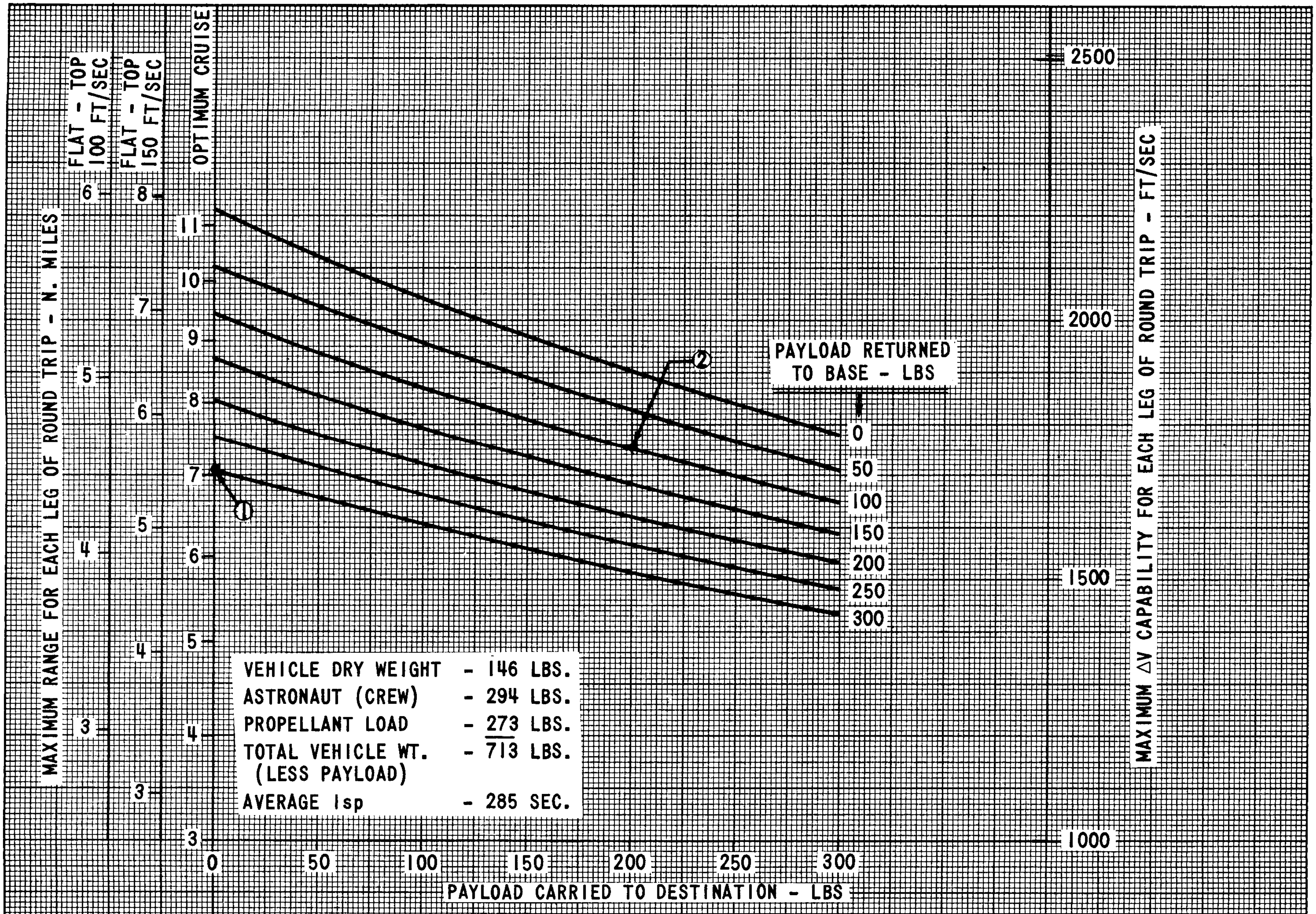

FIGURE 3 - LUNAR FLYING VEHICLE RANGE CAPABILITY vs. PAYLOAD COMBINATIONS

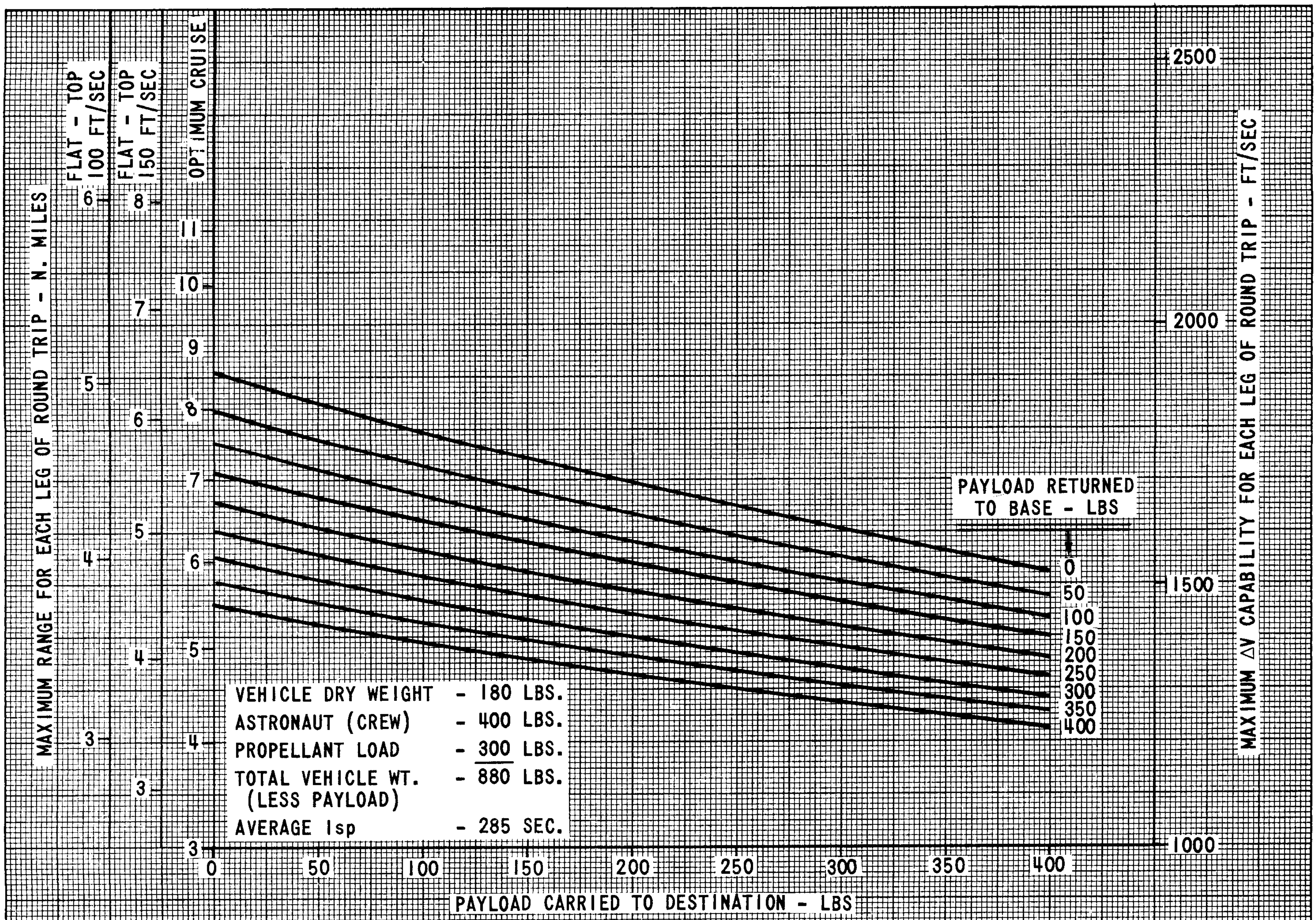

FIGURE 4 - LUNAR FLYING VEHICLE RANGE CAPABILITY vs. PAYLOAD COMBINATIONS

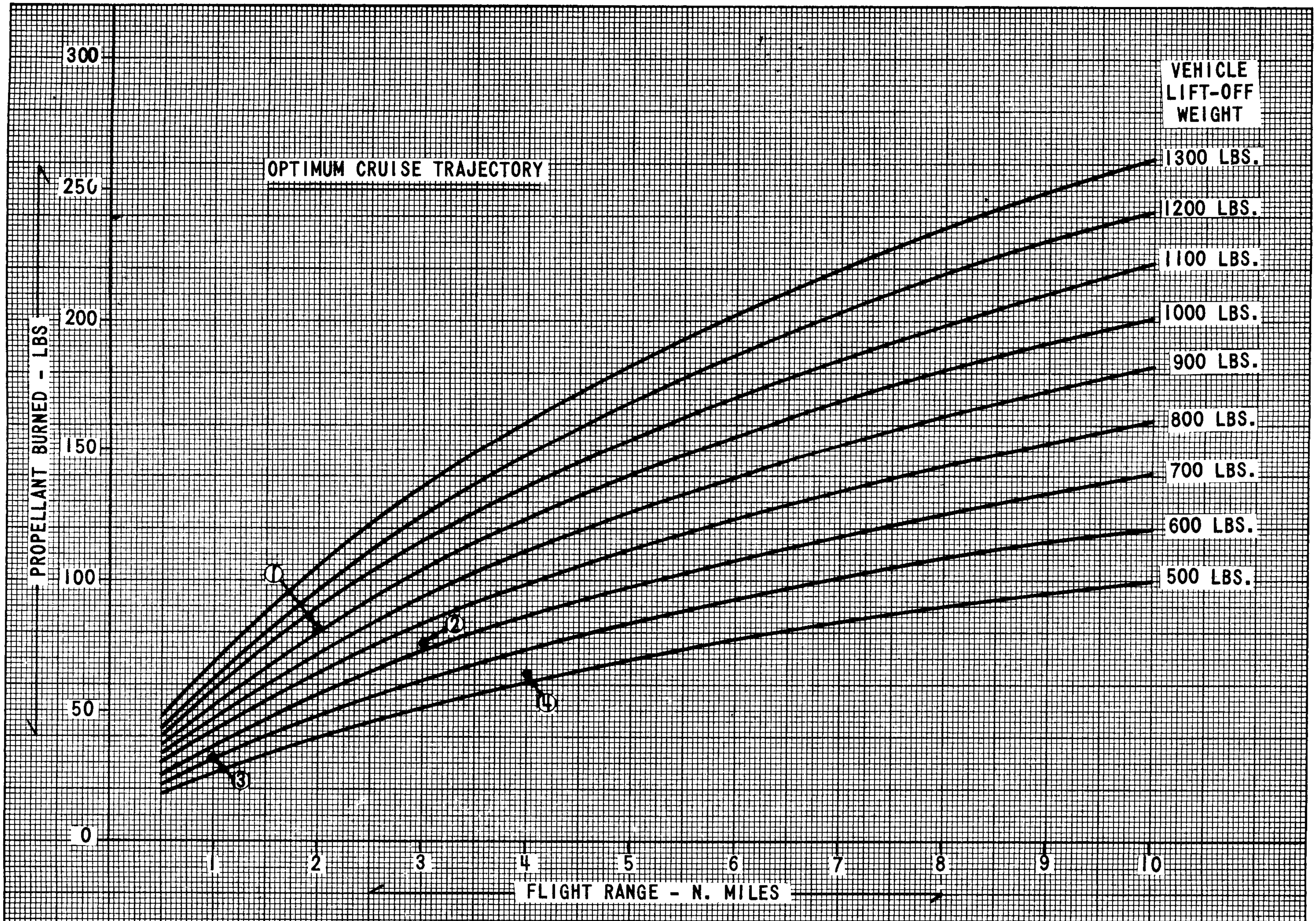

FIGURE 5 - LUNAR FLYING UNIT PROPELLANT REQUIREMENTS vs. FLIGHT RANGE

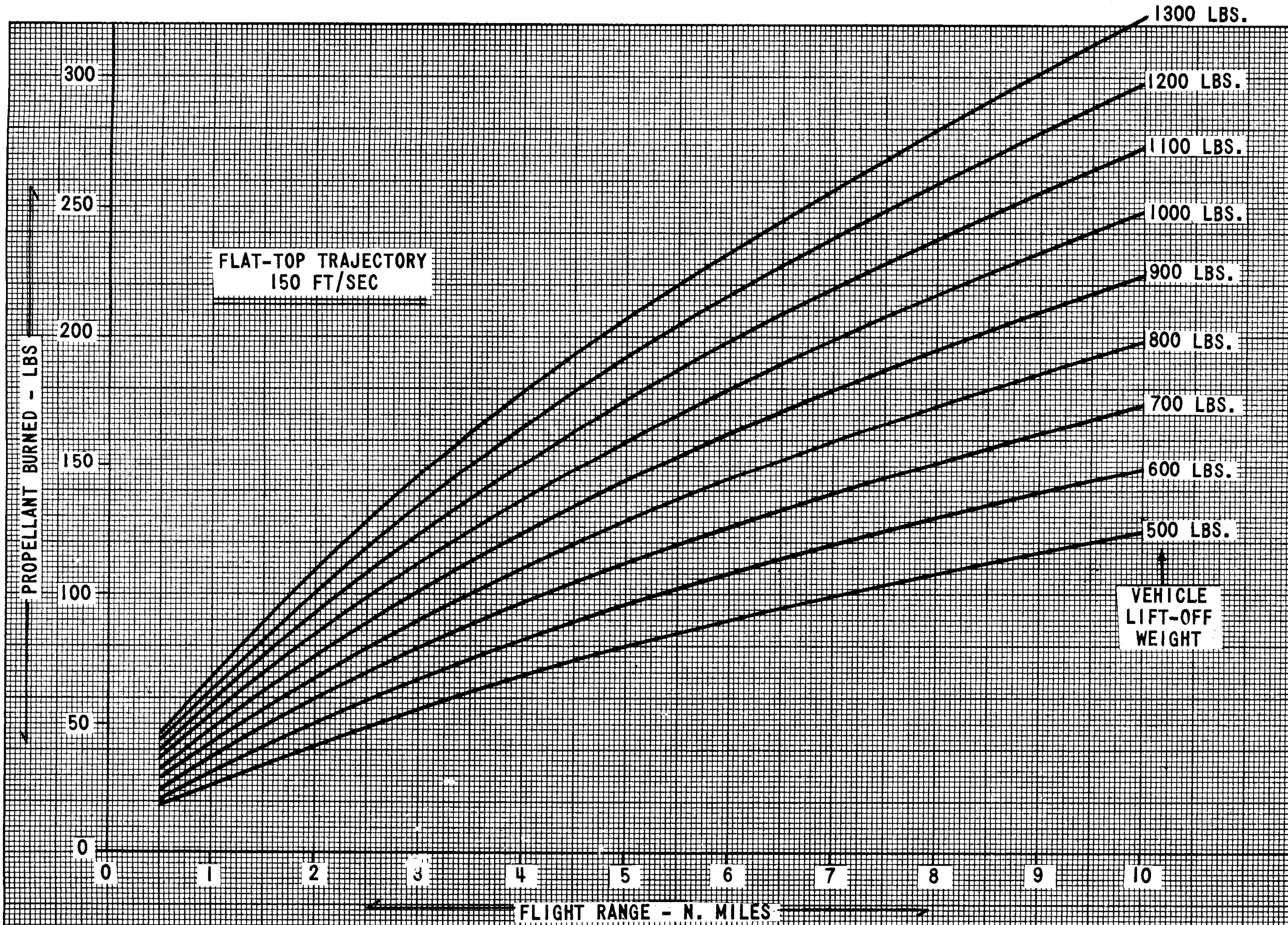

FIGURE 6 - LUNAR FLYING UNIT PROPELLANT REQUIREMENTS vs. FLIGHT RANGE

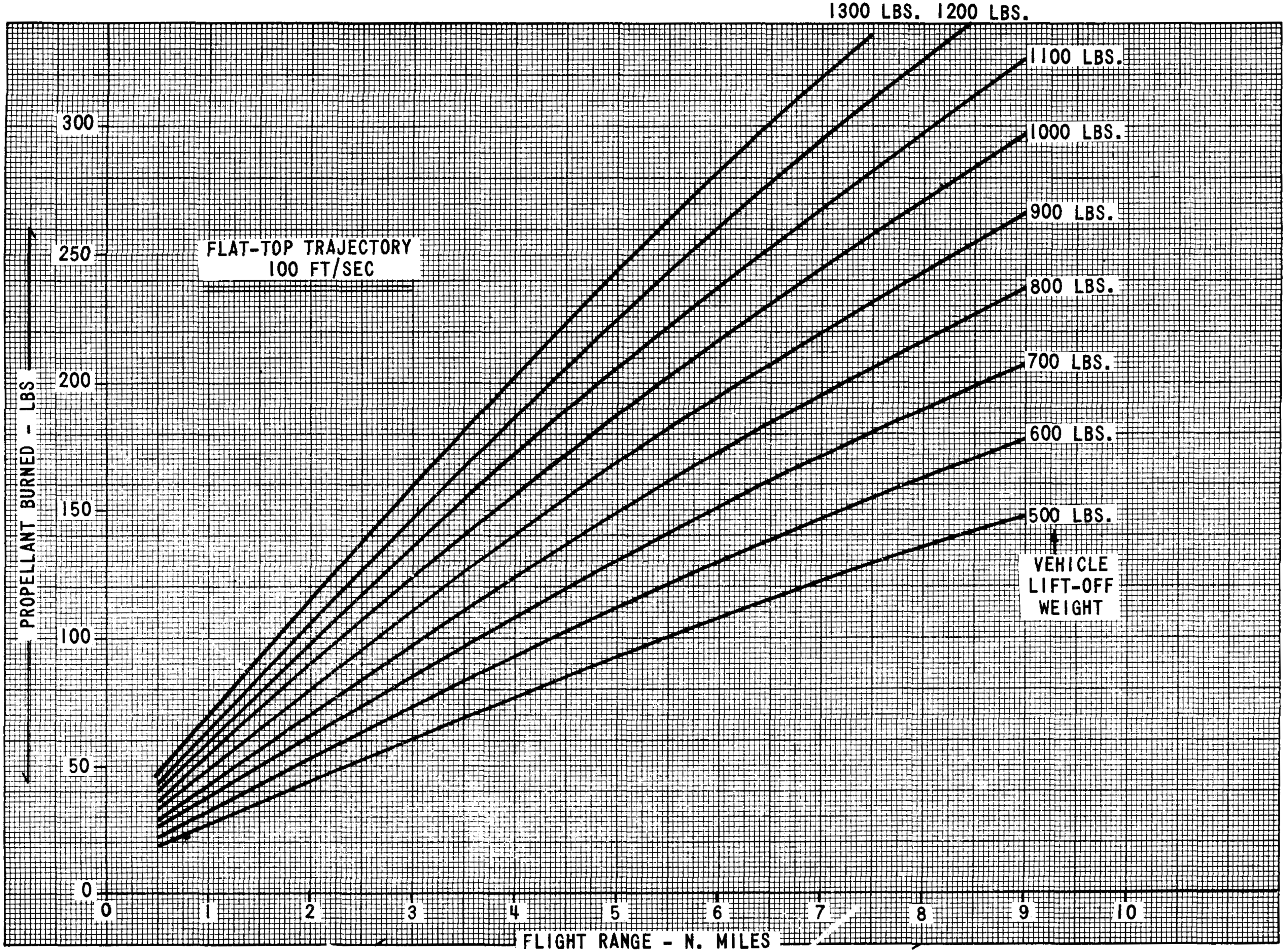

FIGURE 7 - LUNAR FLYING UNIT PROPELLANT REQUIREMENTS vs. FLIGHT RANGE

BELLCOMM, INC.

Subject: Determination of Lunar Flying Vehicle Range and Payload Capabilities for Mission Planning Purposes

From: D. R. Valley

Distribution List

NASA Headquarters

Messrs. R. J. Allenby/SL
W. O. Armstrong/MTX
D. A. Beattie/MTL
E. M. Cortright/MT
P. E. Culbertson/MLA
F. P. Dixon/MTY
P. Grosz/MTL
E. W. Hall/MTG
R. W. Johnson/MTL
T. A. Keegan/MA-2
D. R. Lord/MTD
M. W. Molloy/SL
W. T. O'Bryant/SL
M. J. Raffensperger/MTE
L. Reiffel/MA-6
W. H. Rock/MLR
L. R. Scherer/SL
A. D. Schnyer/MTV
J. H. Turnock/MA-4
M. G. Waugh/MTP

ARC

Mr. L. Roberts/202-5 (2)

MSFC

Messrs. L. L. Bradford/R-AS-P
R. D. Stewart/I-SS-AA
O. H. Vaughn/R-AERO-Y

MSC

Messrs. J. M. Eggleston/TH
J. Funk/FM8
H. E. Gartrell/KF
W. N. Hess/TA
T. R. Kloves/ET
A. J. Meyer/ET
W. E. Stoney/ET

Jet Propulsion Laboratory

Mr. J. D. Burke/111-100 (2)

Bellcomm, Inc.

Messrs. F. G. Allen
G. M. Anderson
D. R. Anselmo
A. P. Boysen, Jr.
J. P. Downs
J. Gillespie
D. R. Hagner
P. L. Havenstein
W. C. Hittinger
B. T. Howard
D. B. James
J. Kranton
K. E. Martersteck
R. K. McFarland
J. Z. Menard
V. S. Mummert
I. D. Nehama
G. T. Orrok
J. W. Powers
T. L. Powers
I. M. Ross
J. M. Tschirgi
R. L. Wagner
J. E. Waldo
All Members Division 101
Department 1023
Central File
Library